Perspective

Sonography of the Normal Fetal Heart: A Practical Approach

Mary C. Frates[1]

Routine prenatal sonography of the fetal heart during the second and third trimesters has traditionally been limited to the four-chamber view. In recent years, the addition of great vessel imaging has been proposed as critical for improved prenatal diagnosis of congenital heart disease. When images of the aortic and pulmonary outflow tracts are included in the fetal cardiac examination, an additional 25% of the congenital heart anomalies are detected than are diagnosed by the four-chamber view alone [1–5]. However, obtaining these additional images has not become a standard part of the examination for sonography practitioners. One explanation for the lack of expansion of the cardiac survey may be the perceived difficulty in obtaining images of the outflow tracts. Neither physicians nor sonographers have a resource that clearly explains the maneuvers needed to obtain these views. The purpose of this essay is to describe and provide illustrations of the sonographic techniques that can be used to perform a more complete fetal cardiac survey during routine obstetric sonography. This method uses the imager's knowledge of anatomy, chest radiography, and chest CT to provide the groundwork required to understand and perform the essentials of prenatal cardiac examination.

Background

Congenital heart disease occurs in 0.4–0.8% of all pregnancies [6–8]. The incidence increases to 4% in a fetus with an affected sibling, to 9% if the father has congenital heart disease, and to 12% if the mother has congenital heart disease. Other risk factors for congenital heart disease include diabetes mellitus (nongestational), drug use (anticonvulsants, alcohol, retinoic acid, lithium), maternal infection (e.g., rubella), and lupus [9, 10]. In addition to these risk factors, there is a high frequency of congenital heart disease in association with other structural or chromosomal abnormalities [11]. Therefore, when a noncardiac fetal anomaly is found, a complete cardiac examination becomes even more critical. Despite the known risk factors for congenital heart disease, most affected fetuses have no identifiable risk factors. Thus, all fetuses should undergo as complete a cardiac examination as possible. Unfortunately, malformations affecting the heart are the most frequently missed of all fetal anomalies [12–14]. One explanation for this deficiency is that the diagnostic accuracy of prenatal sonography for cardiac defects is only 33–63% when a four-chamber view alone is obtained. With the addition of the outflow tract views, the accuracy increases to as high as 83–85% [1–3, 5]. The need to understand and obtain views of the great vessel outflow tracts is clear.

If a cardiac anomaly is not recognized during a screening examination, the outcome could be catastrophic. For most sonographers and sonologists, the identification of an abnormality will be the critical step and will prompt referral to a tertiary center for formal fetal echocardiography and possible postnatal management.

In my experience, most fetuses in the late second and third trimesters are in the vertex position with the left side down (Fig. 1). Understanding the fetal heart in this position is the essential component of the following techniques. Once the anatomy is understood and this group of fetuses can be successfully imaged consistently, the cardiac examination can be completed in most patients. After mastering the technique needed to image a fetus who is in the

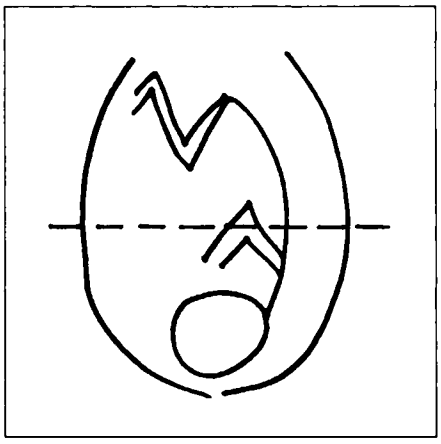

Fig. 1.—Line drawing shows fetus within uterus in vertex position with left side down. Transverse line drawn across image represents plane of imaging for four-chamber view of heart.

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[1]Department of Radiology, Brigham and Women's Hospital, 75 Francis St., Boston, MA 02115. Address correspondence to M. C. Frates.

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vertex position with the left side down, the suggested maneuvers can be applied to fetuses in other positions and presentations. Subsequently, the cardiac examination techniques can be applied to fetuses in the early second trimester when positions are quite variable but diagnosis of congenital heart disease is highly desirable.

Techniques

Four-Chamber View

The four-chamber view is a straightforward axial image obtained with a transverse view of the fetal chest. Unlike the adult heart, the fetal heart sits horizontally in the chest as a result of the prominence of the fetal liver [15]. Shadowing created by the fetal rib cage can be diminished by sliding the probe slightly to the mother's right, and imaging from a more anterior point on the fetal chest wall. The apex of the heart should point to the left (i.e., point down in a fetus who is in the vertex position with the left side down) approximately 45° from a line drawn between the spine and the sternum (Fig. 2). The heart should fill approximately one third to one half of the volume of the chest, and the right-sided chambers should be equal to or slightly larger than the left-sided chambers. Similar to its appearance on a chest CT scan, the chamber closest to the spine is the left atrium and the chamber behind the sternum is the right ventricle. Both the mitral and tricuspid valves are seen in this axial plane. A thin, hypoechoic outer rim of the myocardium can be identified in most fetuses (Fig. 3) and should not be confused with pericardial fluid [16] (Fig. 4). A sliver (<2 mm) of pericardial fluid is occasionally appreciated and can be considered insignificant, but larger amounts of fluid should prompt a search for other abnormalities [17].

Posterior to the heart and adjacent to the left edge of the thoracic spine on the four-chamber view, a single great vessel is normally seen. This structure is the descending aorta because both superior and inferior vena cavae have emptied into the right atrium at levels above and below the four-chamber view, respectively. If two large vessels are seen in the expected location of the descending aorta on the four-chamber view, interruption of the inferior vena cava with azygous continuation is likely [18].

Aortic Outflow Tract

Obtaining the required image of the aortic outflow tract requires angling the probe toward the right shoulder of the fetus from the baseline four-chamber view. As a basis for understanding

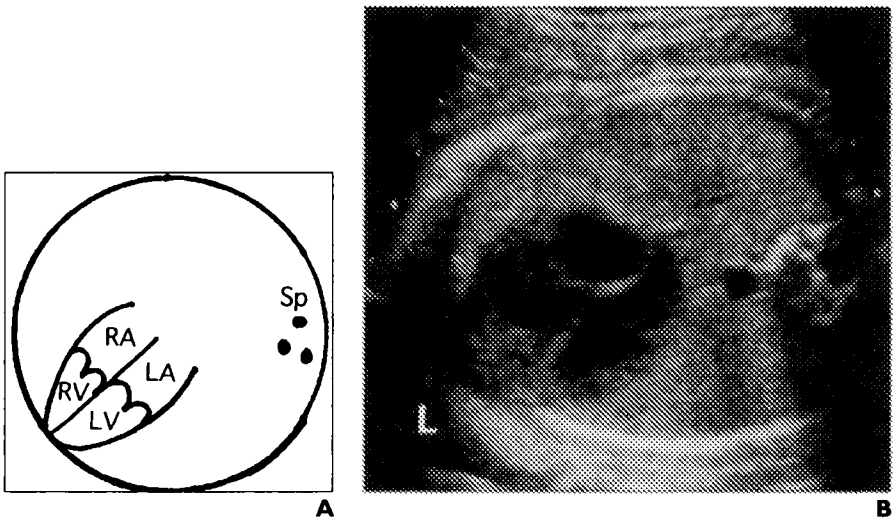

Fig. 2.—Four-chamber view of heart in fetus at 18 weeks gestational age; fetus is in vertex position with left side down. L = fetal left side.
A, Line drawing of transverse image of fetal chest shows four-chamber view of heart. LA = left atrium, LV = left ventricle, RA = right atrium, RV = right ventricle, Sp = spine.
B, Corresponding transverse sonogram of fetal chest reveals that cardiac apex points down and to fetal left (L).

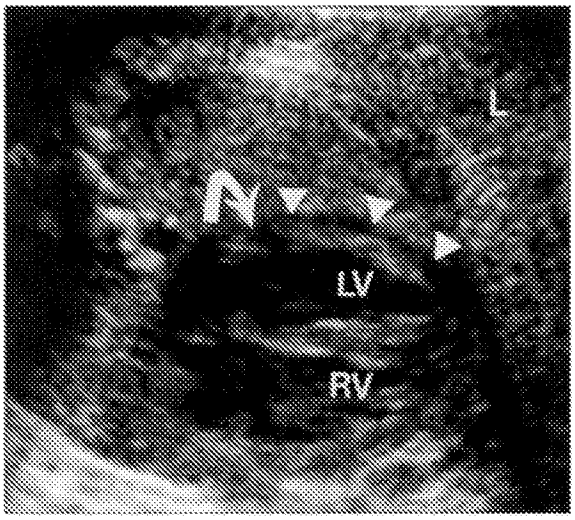

Fig. 3.—Pseudopericardial effusion in fetus at 30 weeks gestational age; fetus is in vertex position with right side down. Transverse sonogram of chest shows normal hypoechoic rim of myocardium (*arrowheads*). Note rim ends at level of mitral valve (*arrow*). LV = left ventricle, RV = right ventricle, L = fetal left side.

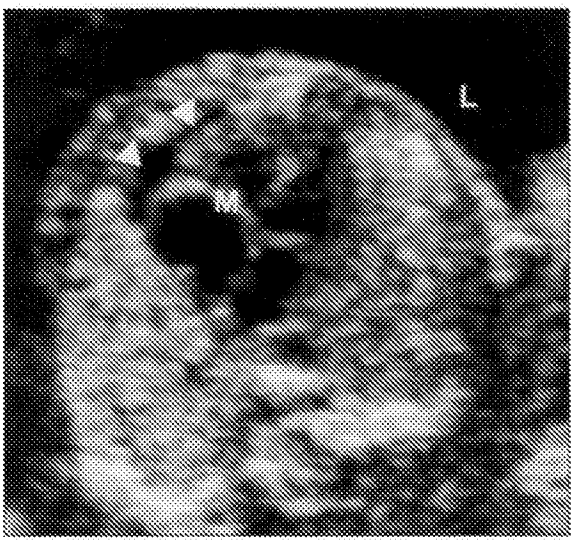

Fig. 4.—Pericardial effusion in fetus at 17 weeks gestational age; fetus is supine and in breech position. Transverse sonogram of chest shows small, anechoic effusion (*arrowheads*) crossing at level of mitral valve (M). L = fetal left side.

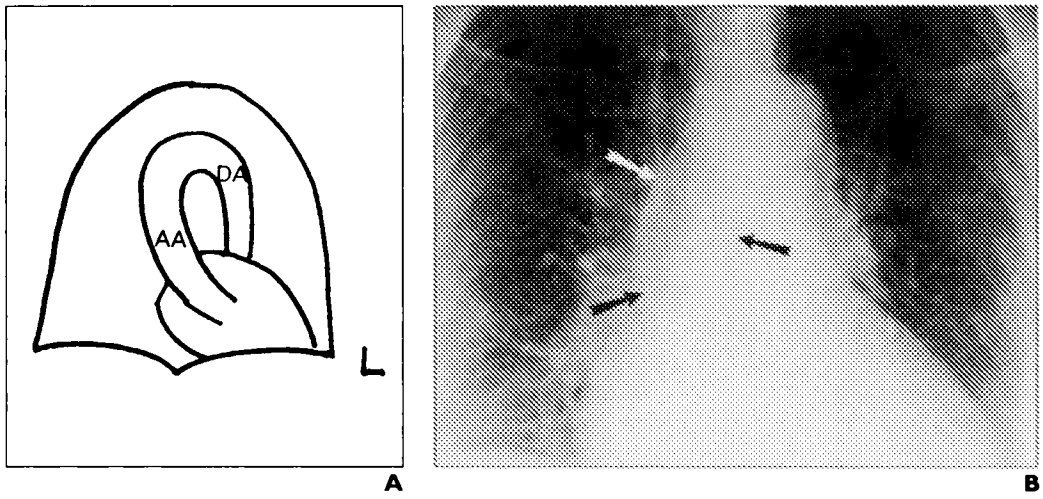

Fig. 5.—Aortic outflow tract of 74-year-old woman with cough.
A, Line drawing of ascending aorta. AA = ascending aorta, DA = descending aorta, L = adult left side.
B, Corresponding chest radiograph shows outline of calcified ascending aorta (*arrows*).

this technique, it is useful to refer to the chest radiograph of a patient with a tortuous aorta (Fig. 5). The aorta extends out of the left ventricle directly toward the right shoulder. One can draw an imaginary line from the stomach bubble in the left upper quadrant to the right shoulder and find a plane parallel to the aortic outflow tract. This plane is the one to reproduce in the fetus.

To translate this information into use in a fetus in the vertex position with the left side down, begin with the four-chamber view. While keeping the side of the transducer closest to your thumb on the left ventricle, gently angle the far side of the probe (i.e., the side closest to your pinkie) toward the mother's feet (i.e., where the shoulder and head of a fetus in a vertex position are located) and simultaneously lift the far side of the probe toward the ceiling (the right shoulder is up in a fetus with the left side down). Watch carefully to ensure that the left ventricle remains visible as you angle the probe. This combined wrist tilt and pinkie lift will result in the longitudinal aortic outflow view (Fig. 6). Note that the aorta both crosses midline and is directed cranially.

Once the aortic outflow image is obtained, pay particular attention to the top of the ventricular septum as it merges with the medial wall of the ascending aorta. This site is where most ventricular septal defects occur (Fig. 6B). In addition, this view shows an overriding aorta in patients with tetralogy of Fallot (Fig. 7), parallel great vessels in transposition (Fig. 8), or a single great vessel with a truncus arteriosus.

To confirm that the great vessel seen using this technique is the aorta, follow the vessel to the top of its arch and note the origins of the carotid and subclavian arteries.

Pulmonary Outflow Tract

To image the pulmonary outflow tract, no significant angling of the transducer is

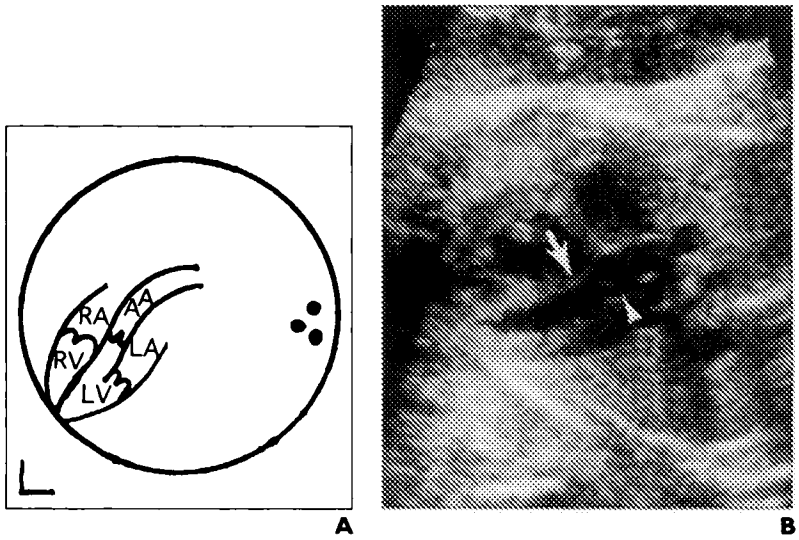

Fig. 6.—Aortic outflow tract in fetus at 18 weeks gestational age (same fetus as shown in Fig. 2B); fetus is in vertex position with left side down.
A, Line drawing shows fetal aorta exiting left ventricle and extending toward right shoulder. LA = left atrium, LV = left ventricle, RA = right atrium, RV = right ventricle, AA = ascending aorta, L = fetal left side.
B, Corresponding sonogram of aortic outflow tract. Leaflets of aortic valve are marked by arrowhead. Arrow marks site of most ventriculoseptal defects.

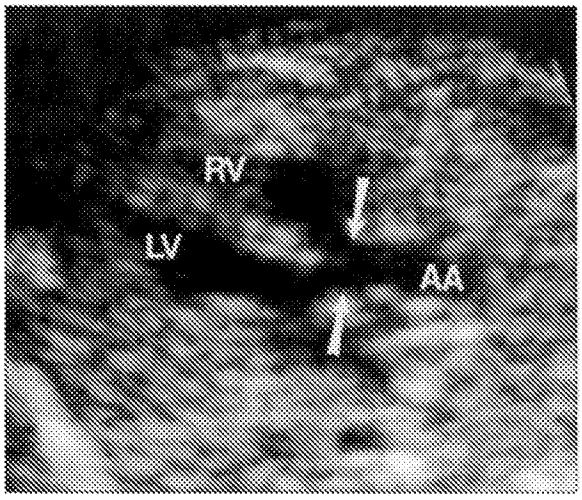

Fig. 7.—Tetralogy of Fallot in fetus at 21 weeks gestational age; fetus is supine and in vertex position. Transverse sonogram of chest shows overriding aorta (*arrows*) that originates from both left and right ventricles. LV = left ventricle, RV = right ventricle, AA = ascending aorta.

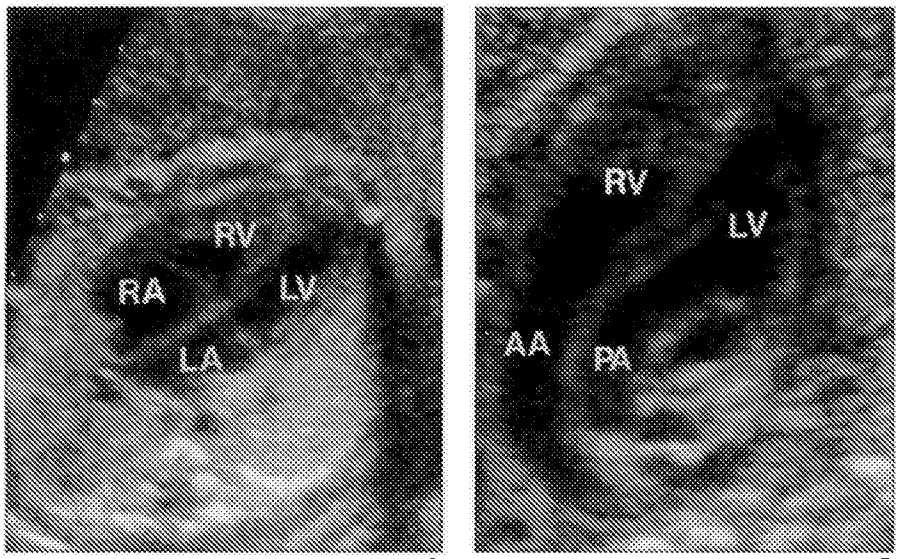

Fig. 8.—Transposition of great arteries in fetus at 30 weeks gestational age; fetus is supine and in breech position. LV = left ventricle, RV = right ventricle. (Courtesy of Di Salvo DN, Boston, MA)
A, Transverse sonogram shows normal four-chamber view of heart. LA = left atrium, RA = right atrium.
B, Transverse sonogram of outflow tract view shows parallel great vessels. Note aorta arises from right ventricle and pulmonary artery arises from left ventricle. AA = ascending aorta, PA = pulmonary artery.

required: From the four-chamber view, just slide the probe toward the head of the fetus.

Consider the technique used to obtain a CT scan of the chest. In nearly every patient, an image of the main pulmonary artery is obtained at the level at which it bifurcates into the right and left pulmonary arteries (Fig. 9). When chest CT is performed, the gantry is not angled, and the patient's position is not altered. The pulmonary artery and its branches are seen on a true transverse image. Note that right and left are inverted on the CT scan when compared with right and left in the vertex fetus; the images obtained on chest CT, with the patient's head through the far side of the gantry, are similar in orientation to those from a breech fetus.

To image the pulmonary outflow tract in the fetus in the vertex position, begin again with the four-chamber view. Next, slide the probe toward the mother's feet (i.e., toward the head of the fetus) as if you are obtaining a chest CT scan of the fetus. In the transverse or axial plane that is just cranial to the four-chamber view, the main pulmonary artery can be seen to arise from the right ventricle, travel posteriorly just to the left of midline, and bifurcate into the right pulmonary artery and the ductus arteriosus (Fig. 10). The right pulmonary artery wraps around a cross section of the ascending aorta. The ductus arteriosus can be followed to its insertion into the descending aorta, just to the left of the fetal spine. The left pulmonary artery is typically not identified. The pulmonary valve can be evaluated just proximal to the bifurcation. In many fetuses, once the pulmonary artery is identified, slight angling or tipping of the probe may be required while sliding it cranially, to elongate the full extent of the pulmonary artery and its bifurcation.

For many beginners, knowing where in the chest to look for the pulmonary artery is the most difficult part of the examination. When learning to image the pulmonary artery, it is extremely useful to first locate the fetal stomach. From the four-chamber view, slide the probe caudally in the fetus, which is toward the mother's head, and identify the stomach on the same side as the cardiac apex (down in the fetus in the vertex position with the left side down). Next, slide the probe cranially in the fetus through the level of the four-chamber view (note the apex points left) and continue slightly farther. Look on the same side as the stomach for the curve of the pulmonary artery (Fig. 10). The stomach, left ventricular apex, and pulmonary artery must always be on the same side (left). This confirmation of situs solitus is necessary in every fetus and provides a useful check even for the experienced sonographer. The maneuver also helps localize pulmonary arteries in the fetus at an early gestational age who is small, active, and changing position as you scan; in breech fetuses; and in multiple gestations in which fetal parts overlap.

When imaging the outflow tracts, confirm that the great vessels cross at their origins: on the longitudinal view of the aorta, the pulmonary artery should be seen in cross section only, and on the longitudinal view of the pulmonary artery, the aorta should be seen in cross section only. Two different maneuvers are required to obtain each longitudinal view in the healthy fetus. Crossing of the great vessels helps exclude both transposition of the great arteries and truncus arteriosus. These entities can be diagnosed prenatally if the outflow tracts are evaluated.

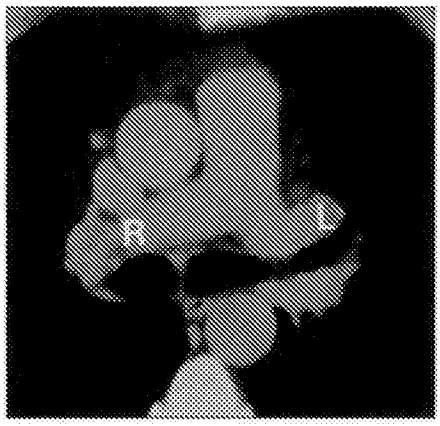

Fig. 9.—CT scan of chest in 63-year-old man with interstitial lung disease shows main pulmonary artery and its bifurcation into right and left branches. R = right pulmonary artery, L = left pulmonary artery.

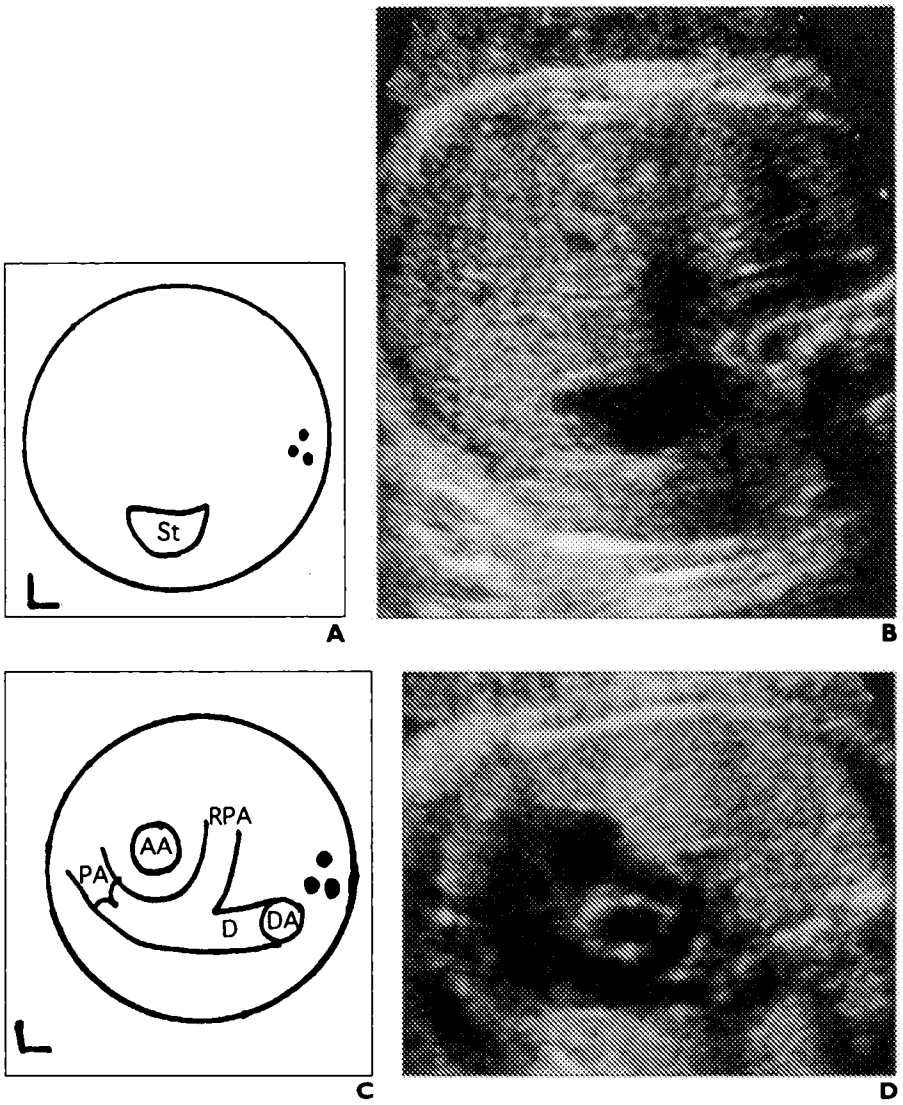

Fig. 10.—Pulmonary artery outflow tract and stomach in fetus at 18 weeks gestational age (also shown in Fig. 2B); fetus is in vertex position with left side down.
A, Line drawing of transverse fetal abdomen in which stomach is shown. St = stomach, L = fetal left side.
B, Corresponding axial sonogram of fetal abdomen shows stomach filled with fluid.
C, Line drawing of transverse fetal chest outlines pulmonary outflow tract. PA = pulmonary artery, RPA = right pulmonary artery, D = ductus arteriosus, AA = ascending aorta, DA = descending aorta, L = fetal left side.
D, Corresponding sonogram of fetal chest shows pulmonary outflow tract.

When beginning to learn how to perform the cardiac survey of a fetus, focus your efforts on the examination of fetuses whose left side is directed down and limit the time devoted to the examination of fetuses in other positions. Once you can consistently image fetuses who are in the vertex position with the left side down, attempt the maneuvers on fetuses who are in other positions (Figs. 11 and 12). It is overwhelming, confusing, and unnecessary to try to master all fetal positions at once.

When imaging a fetus with possible congenital heart disease, obtain the basic images described to attempt to make a diagnosis: begin with the four-chamber view and then move to the outflow tracts (Fig. 13). If the diagnosis is unclear, more information is likely necessary. Although the superior vena cava, inferior vena cava, and pulmonary veins are not part of the cardiac examination described here, evaluation of these structures may provide added information, particularly in fetuses with heterotaxy (asplenia or polysplenia). Referral to a fetal echocardiographer should be considered whenever congenital heart disease is identified.

Summary

Understanding the basic techniques of and having an organized approach to the cardiac examination of fetuses will allow an experienced sonographer or sonologist to obtain the necessary images to diagnose many types of congenital

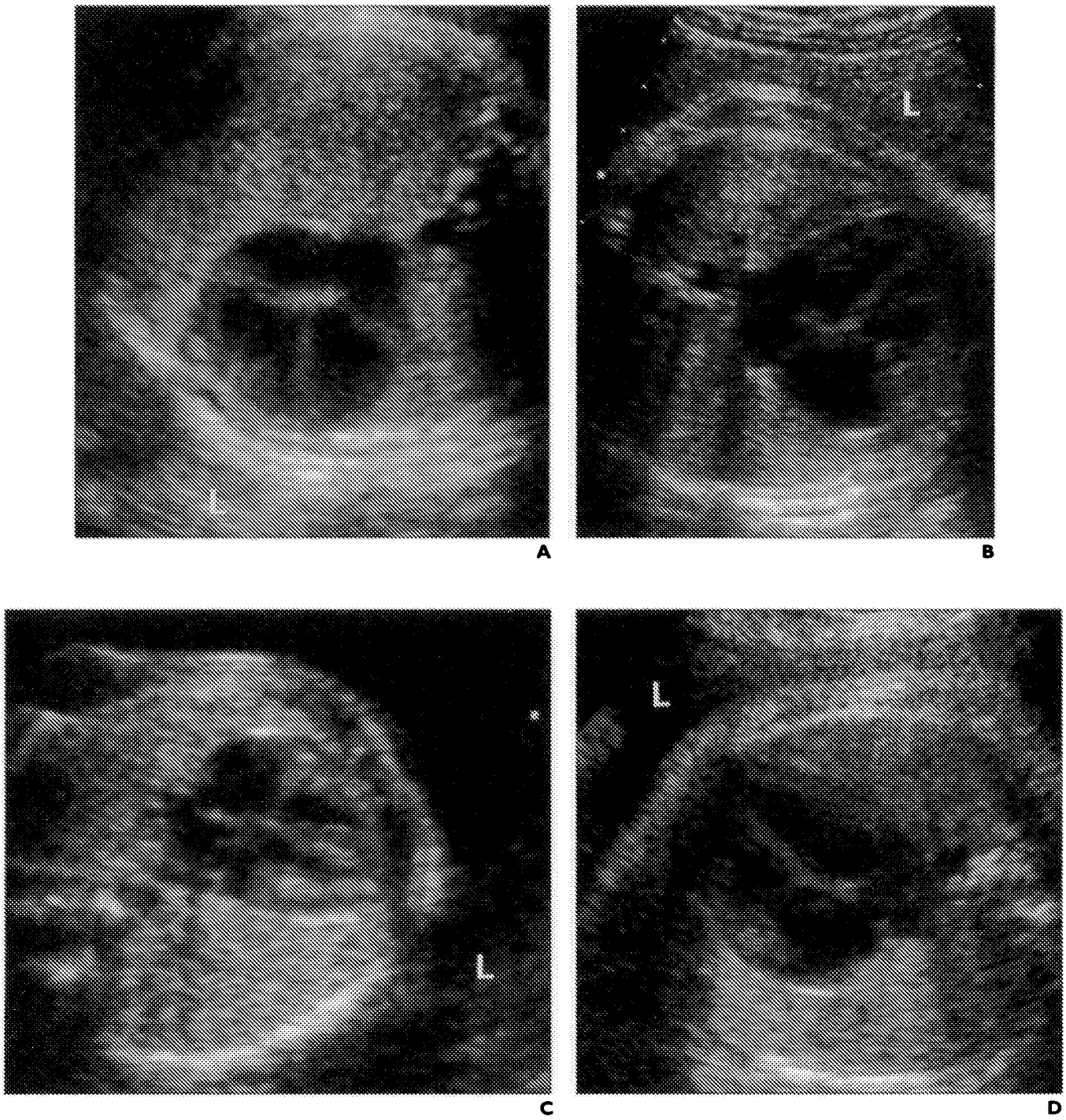

Fig. 11.—Four-chamber view of heart in fetuses in variety of positions. L = fetal left side.
A, Fetus (gestational age, 34 weeks) in vertex position with left side down.
B. Fetus (gestational age, 36 weeks) in vertex position with right side down.
C, Fetus (gestational age, 19 weeks) in breech position with left side down.
D, Fetus (gestational age, 31 weeks) in breech position with right side down.

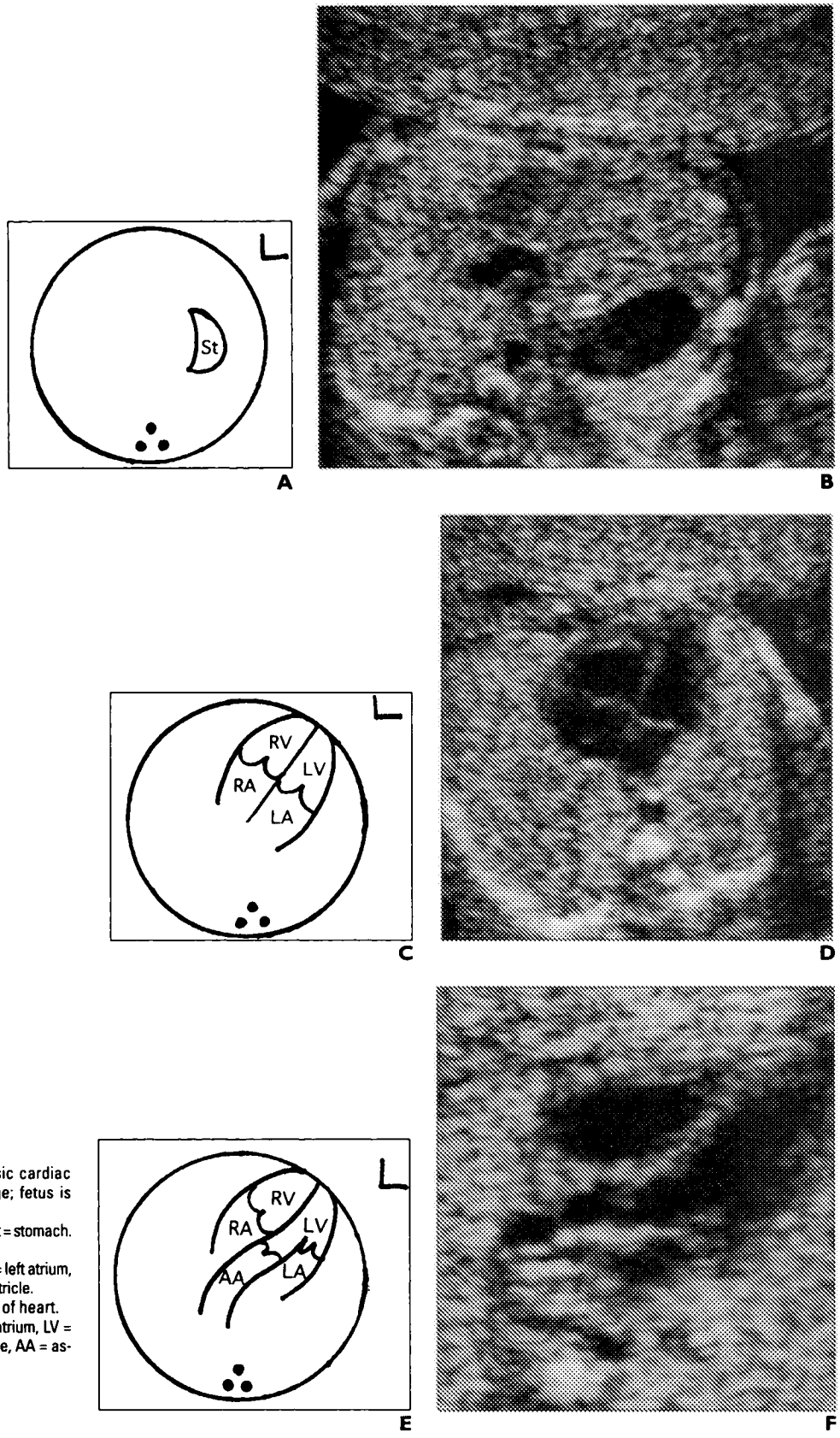

Fig. 12.—Line drawings and sonograms of basic cardiac examination fetus at 23 weeks gestational age; fetus is supine and in breech position.
A, Line diagram of fetal stomach. L = fetal left side, St = stomach.
B, Transverse sonogram of fetal stomach.
C, Line diagram of four-chamber view of heart. LA = left atrium, LV = left ventricle, RA = right atrium, RV = right ventricle.
D, Transverse sonogram of four-chamber view of heart.
E, Line diagram of aortic outflow tract. LA = left atrium, LV = left ventricle, RA = right atrium, RV = right ventricle, AA = ascending aorta.
F, Sonogram of aortic outflow tract.
(Fig. 12 continues on next page)

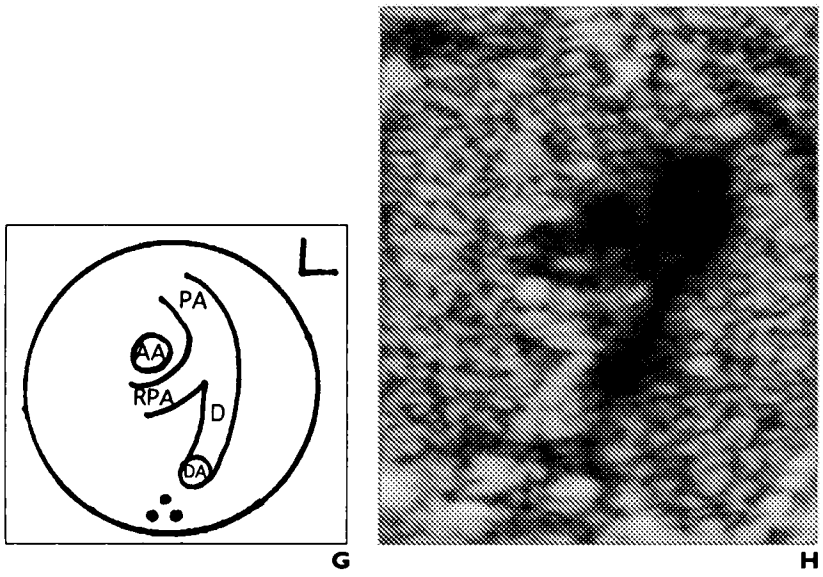

Fig. 12. (Continued)—Line drawings and sonograms of basic cardiac examination fetus at 23 weeks gestational age; fetus is supine and in breech position.
G, Line diagram of pulmonary outflow tract. PA = pulmonary artery, RPA = right pulmonary artery, D = ductus arteriosus, AA = ascending aorta, DA = descending aorta.
H, Sonogram of pulmonary outflow tract.

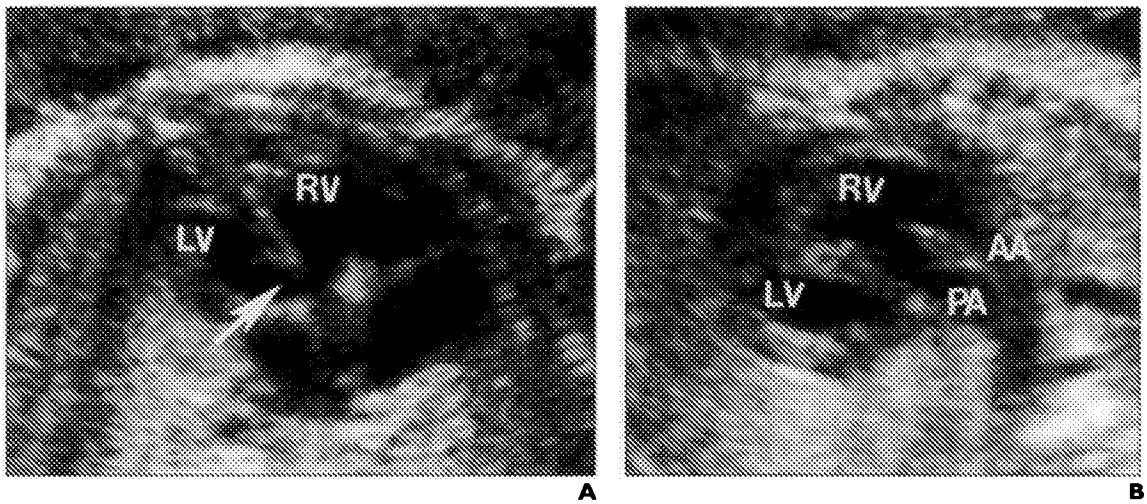

Fig. 13.—Double-outlet right ventricle in fetus at 31 weeks gestational age; fetus is in vertex position and is supine. LV = left ventricle, RV = right ventricle.
A, Transverse sonogram of four-chamber view shows abnormality: small left-sided chambers and ventriculoseptal defect at top of intraventricular septum (*arrow*). However, full extent of malformation is not appreciated on this view alone.
B, Longitudinal sonogram of outflow tract view shows both great vessels arising from right ventricle. AA = ascending aorta, PA = pulmonary artery.

heart disease. Although confirmation of congenital heart disease is best performed by formal fetal echocardiography at a tertiary center, the ability to identify fetuses requiring additional examination is invaluable.

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